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Achieving Control of Coating Process in your Foundry

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Abstract

Achieving control of coating thickness in foundry moulds is needed in order to guarantee uniform properties of the mould but also to achieve control of drying time. Since drying time of water based coatings is heavily dependent on the amount of water present in the coating layer, a stable coating process is prerequisite for a stable drying process. In this study, we analyse the effect of different variables on the coating layer properties. We start by considering four critical variables identified in a previous study such as sand compaction, coating density, dipping time and gravity and then we add centre points to the original experimental plans to identify possible non-linear effects and variation in process stability. Finally, we investigate the relation between coating penetration (a variable that is relatively simple to measure in production) and other coating layer thickness properties (relevant for the drying process design). Correlations are found and equations are provided. In particular it is found that water thickness can be directly correlated to penetration with a simple linear equation and without the need to account for other variables.

Keywords: Innovative moulding technologies and materials, Quality management, Coating process control, Sand compaction, Coating penetration

1. Introduction

Since the introduction of water based foundry coatings in the recent years, controlling drying time has become an important issue for many foundries [1]. Coating thickness stability in foundry moulds is needed in order to guarantee uniform properties of the mould. This allows to reach control of drying time [1,2] (by limiting the amount of water deposited on the mould) but also to improve casting quality by reducing the chance of moisture related defects and improving surface quality [3,4].

For a given sand recipe the most important parameters for the control of coating thickness properties are compaction, coating density, dipping time and gravity effects [5]. In this study we

investigate the effect of these variables on the different coating properties and their influence on process stability. Finally we look for correlations between coating penetration (a variable that can be simply be measured in production) and other coating layer thickness properties. Correlations are found and equations provided. In particular it is found that water thickness can be directly correlated to penetration with a simple linear equation.

2. Methods

For this study we consider a cylindrical mould filled with sand and compacted with an aluminium spacer on which different

pressure levels are applied in order to achieve different levels of compaction (Figure 1). The compacted and cured samples are then coated by dipping method using different process parameters (Table 1).



Fig. 1. Pictures of cylindrical mould (left), coated sand sample (centre) and aluminium spacer used for compaction (right)

In Table 1 we can see the different levels used for each variable. Compaction levels are obtained by applying to the mould a pressure calculated by multiplying a standard sand density of 1300 kg/m^3 by the depth of the mould. For this study we choose a pressure equivalent to that under a column of sand 0.2 m, 1.25 m and 2.5 m high. Such pressures are considered representative for large foundry moulds.

Coating density is chosen to represent the minimum, maximum and centre of the specification used in the factories. Dipping times are chosen to represent four cases: a fast pass (2 s), normal pass (5 s), slow pass (15s) and a pool of coating gathering in a cavity of the mould (120 s). Gravity is represented by dipping the sample facing up or down.

Table 1.
Variables considered in this study and correspondent levels used

	Level 1	Level 2	Level 3	Level 4
Compaction	Low (0.2 m)	Medium (1.25 m)	High (2.5 m)	
Coating Density [kg/m³]	1790	1908	2042	
Dipping Time [s]	2	5	15	120
Gravity	Up	Down		

The response variables considered in this study are: sand density $[\text{kg/m}^3]$ (varied density is achieved by compacting sand under different pressures, i.e. compaction level), water thickness $[\text{kg/m}^2]$ (represents the amount of water per square meter of mould), wet thickness $[\text{kg/m}^2]$ (the total amount of coating deposited on the surface of the mould), dry thickness $[\text{kg/m}^2]$ (amount of refractory material deposited in the mould) and coating penetration [mm] (depth reached by the coating layer). The experimental methods are described in full detail in [5]. To estimate the general variation in the experiments several “centre point experiments” were carried out under the following conditions: medium compaction,

coating density of 1908 kg/m^3 , dipping time of 5 seconds and sample facing down.

3. Results

3.1. Main Effects

The first results (Figure 2) show the effect of sand depth (and relative compaction pressure) on the achieved sand density. In the figure we can see that the function is non-linear. In particular sand density decreases significantly for low sand depths and the scatter increases substantially. It is therefore important for small moulds (depth lower than 1 m) to make sure that manual compaction methods and vibration are used.

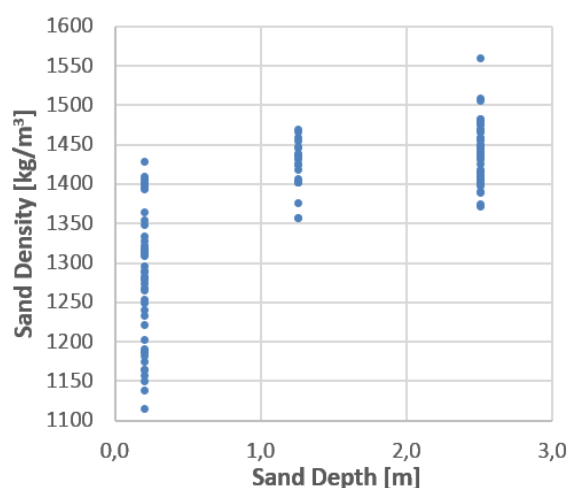


Fig. 2. Sand density of samples as a function of mould depth

Figure 3 shows how water thickness depends heavily on the sand density and scatter increases substantially for sand densities below 1350 kg/m^3 .

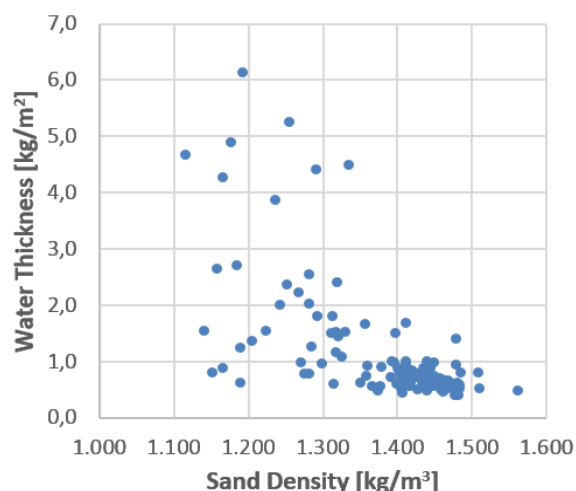


Fig. 3. Water thickness as a function of sand density

The effect of coating density is shown in Figure 4. In this case we see that the scatter in water thickness decreases as the coating density increases. It appears that there is a threshold density above which the scatter is reduced by a factor of 3. The threshold is near a coating density of 2042 kg/m³.

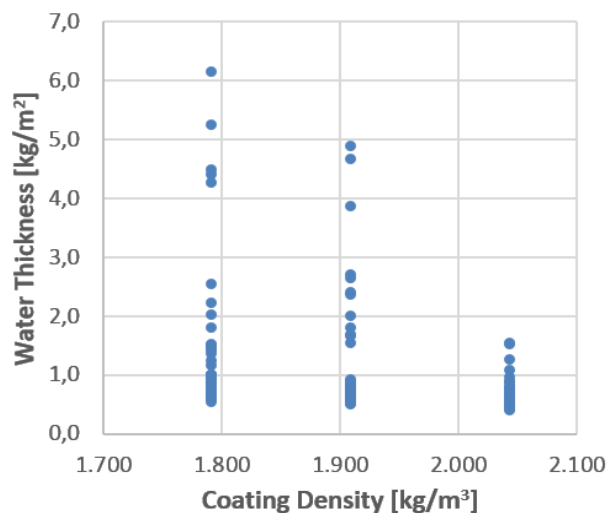


Fig. 4. Water thickness as a function of coating density

The effect of time is represented in Figure 5. Again we see a strong non-linear correlation where water thickness increases substantially with dipping time as well as scatter does. It is therefore important to coat samples with fast passes and avoid pools of coating that will increase substantially the water thickness layer.

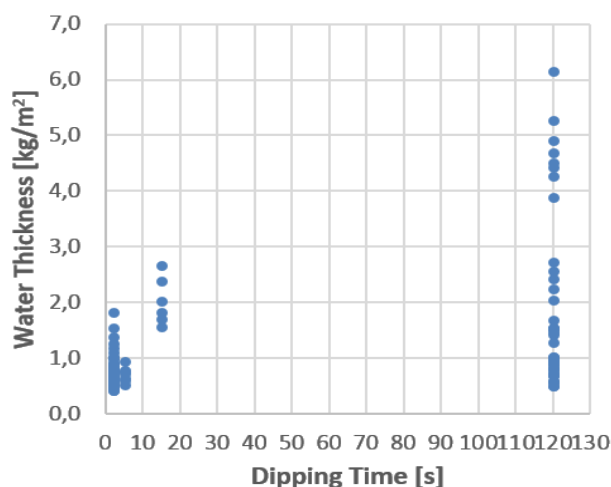


Fig. 5. Water thickness as a function of dipping time

Finally in Figure 6 we can see that for samples facing down, where the coating is applied against gravity, the variation in water thickness is much smaller than for samples coated facing upwards.

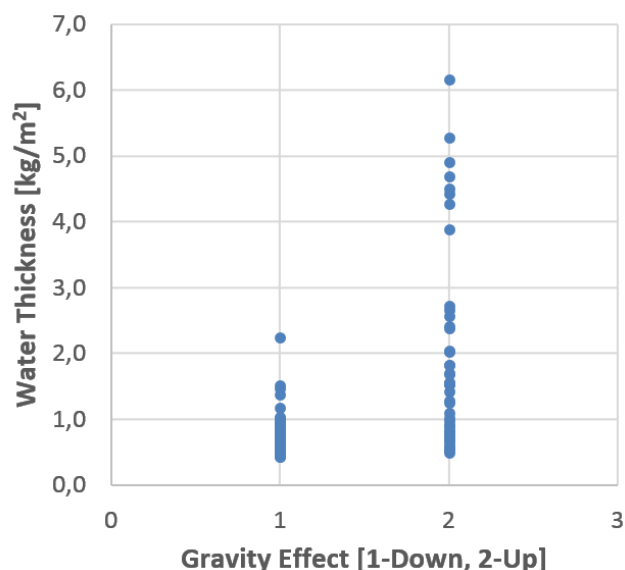


Fig. 6. Water thickness as a function of gravity effect

3.2. Process Control

To investigate the stability of the process, Figure 7 shows the water thickness of several samples coated with the centre point levels of the process parameters (medium compaction, coating density of 1908 kg/m³, dipping time of 5 seconds and sample facing down). We can see how there is a limited amount of scatter and that is possible to control the coating thickness between 0.65 and 0.85 kg/m².

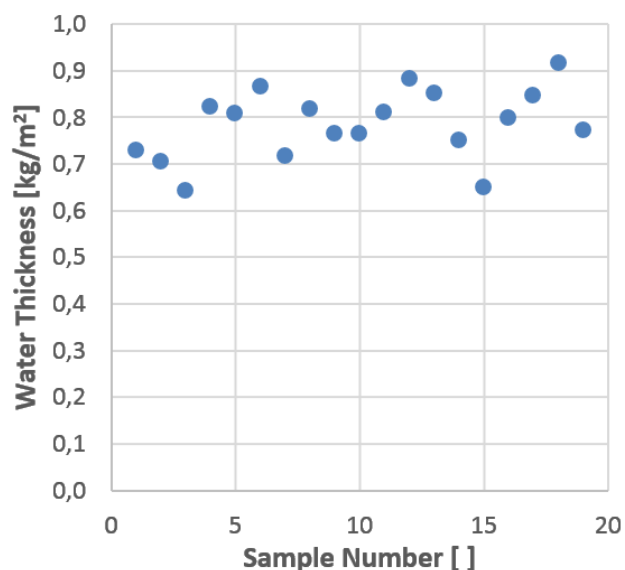


Fig. 7. Water thickness of sample coated with the same coating conditions (medium compaction, coating density of 1908 kg/m³, dipping time of 5 seconds and sample facing down)

3.3. Correlations

In Figure 8 we can see coating layer moisture cannot be correlated to coating penetration but is a clear relation to coating density. Therefore we will not provide a correlation between coating layer moisture and penetration.

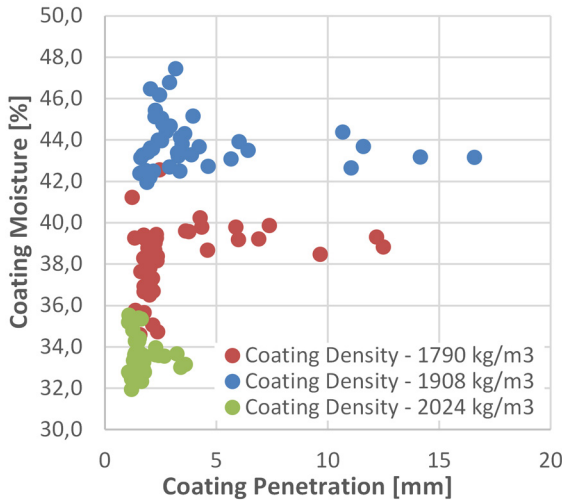


Fig. 8. Coating moisture as function of coating penetration

Figures 9a to 9c show correlations between different coating thickness properties and coating penetration. We can see that, especially for dry thickness (Figure 9a) and wet thickness (Figure 9b) the correlation is heavily dependent on the coating density values. On the other hand, very interestingly, for the water thickness (Figure 9c) there is little dependence of coating penetration on coating density.

Based on the above finding, in order to provide an even simpler correlation for the designers, in Figure 10 we perform a fit of all the data (including the three different coating densities) using a linear function. We obtain a coefficient of correlation of 0.98 % for the below correlation:

$$\text{Water Thickness [kg/m}^2\text{]} = 0.3866 \times \text{Coat. Penetration [mm]}$$

With this equation it will be possible to estimate the amount of water to be dried on a foundry mould or core just by performing a simple penetration measurement and independently of other variables affecting the coating process for thicknesses up to 17 mm.

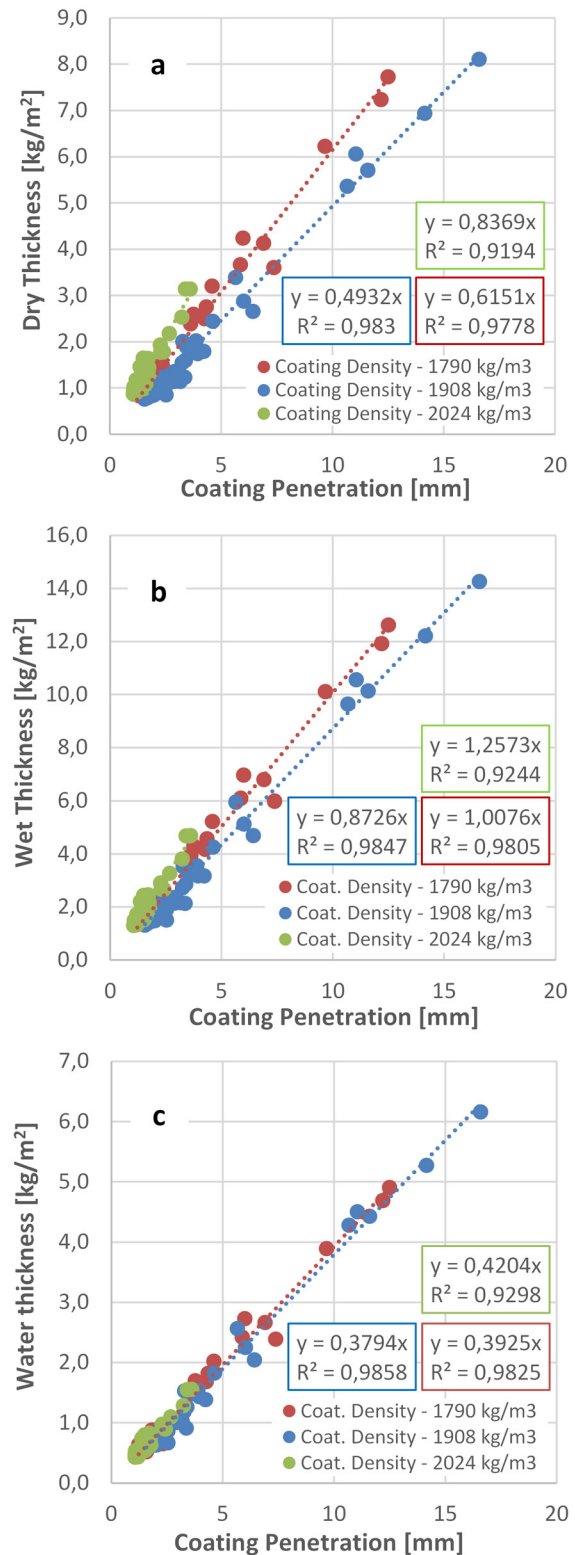


Fig. 9. Dry (a), wet (b) and water (c) thicknesses as a function of penetration with respective correlations

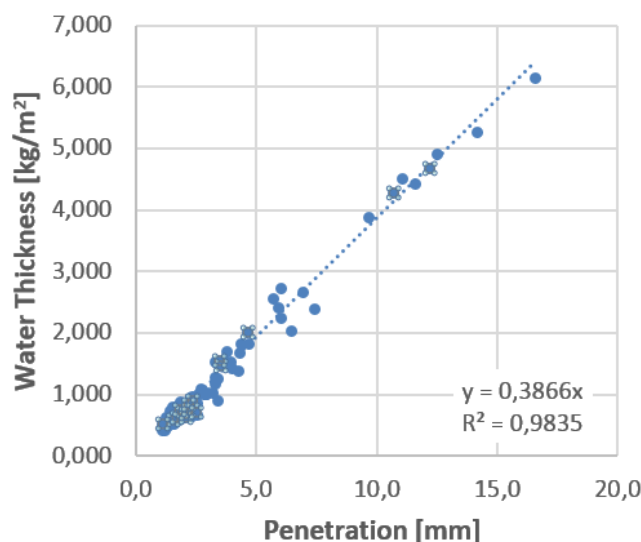


Fig. 10. Water thickness as a function of penetration with overall correlation

4. Conclusions

From the experiments and analysis performed in this study we can conclude that:

- The relations between coating layer properties and coating variables are non-linear.
- The scatter (repeatability) of the coating process is not constant and can be controlled by choosing the right level of moulding and coating parameters.
- In particular to reduce scatter, the sand density should be above 1350 kg/m^3 , the coating density maximized, the

dipping time minimized and moulds should be coated facing downwards.

- It is possible to correlate directly the water thickness and coating penetration independently of other variables and therefore it is possible to estimate water content in coated moulds just by simple penetration measurements.

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